VASCULAR AND ENDOVASCULAR TECHNIQUES

Thomas L. Forbes, MD, Section Editor

Endovascular management of ascending aortic pathology

Ralf R. Kolvenbach, MD, PhD,[a] Ron Karmeli, MD,[b] Lazlo S. Pinter, MD,[a] Yuefeng Zhu, MD,[a] Fan Lin, MD,[a] Sergej Wassiljew, MD,[a] and **Markus Meyer-Gaessner, MD,[a]** *Düsseldorf, Germany; and Haifa, Israel*

Background: **Endovascular treatment of the ascending aorta is particularly challenging because of the anatomic features of this aortic segment. Only patients without connective tissue disorders, clinically relevant aortic regurgitation or stenosis, or concomitant coronary artery disease can be considered for an endovascular procedure. We report our results in a series of patients with aneurysms or intramural hematoma, penetrating ulcers, or floating thrombus who were scheduled for stent grafting.**

Methods: **Only patients with ascending aortic pathology who were unfit for open surgery were treated with an endograft. When preoperative computed tomography imaging showed severe calcification of the aortic arch or thrombus lining, temporary clamping of the carotid arteries before wire and catheter introduction was performed. An extracorporeal bypass from the right groin to both carotid arteries with a roller pump was established and maintained during the procedure. The endograft was placed across the aortic valve into the left ventricle and deployed in a retrograde fashion. At the end of the procedure, ventriculography and, if necessary, coronary angiography was performed to rule out any damage to the left ventricle or the valve apparatus.**

Result: **Eleven patients were scheduled for stent graft exclusion of ascending aortic pathology. In five cases because of discrepancies in length measurements and sizing, the thoracic endograft was cut to length intraoperatively after partial deployment on the operating table and reloaded to avoid covering of the innominate artery. The mean length of the ascending aorta covered was longer in aneurysm patients than in those with dissection. An 81-year-old patient presented with a type Ia leak. The distal landing zone in one patient was enlarged by debranching. One patient died after wire perforation of the left ventricle, and one patient sustained a cerebral stroke. Combined morbidity and mortality was 18%, and the technical success rate was 91%.**

Conclusions: **Stent grafting of the ascending aorta is technically feasible but should be reserved for selected high-risk patients only, preferably in centers where vascular specialists cooperate closely with interventional cardiologists. Cardiac surgery with cardiopulmonary bypass is still the gold standard to treat ascending aortic aneurysms. Stent graft exclusion of more advanced and complex ascending aortic pathology should be performed only in centers with the necessary experience in transvalvular cardiac procedures. (J Vasc Surg 2011;53:1431-8.)**

The incidence of thoracic aortic aneurysms is estimated to be as high as 6 cases/100,000 person-years, and replacement of the ascending aorta accounts for most thoracic aortic procedures. Bicuspid and unicuspid aortic valves are associated with ascending aortic aneurysms and dissections and are still best treated by cardiac surgery, which permits treatment of the abnormal valve along with ascending aortic replacement.

Endovascular management of aortic arch aneurysms is routinely performed in many vascular centers. Aneurysms and dissections of the ascending aorta are still mainly treated operatively with cardiopulmonary bypass: ascending aortic aneurysms with normal sinuses and aortic annulus require only replacement of the ascending aorta from the sinotubular ridge to the origin of the innominate artery with a Dacron tube graft.

Owing to the significant morbidity and mortality of these procedures, high-risk patients are not considered for cardiac surgery. A number of anecdotal reports have described endovascular stent grafting of various pathologies, including deployment of a fenestrated stent graft to repair an ascending aortic rupture.[1-4] Endovascular treatment of the ascending aorta is particularly challenging because of the anatomic features of this aortic segment. Acute and

From Department of Vascular Surgery, Vascular Center Catholic Clinics Duesseldorf Augusta Hospital[a]; and Carmel Medical Center.[b]

Competition of interest: none.

Correspondence: Dr Ralf Kolvenbach, Vascular Center Catholic Clinics Duesseldorf Augusta Hospital, Department of Vascular Surgery, Amalien Str 9, 40472 Duesseldorf, Germany (e-mail: Kolvenbach@VKKD-Kliniken.de).

The editors and reviewers of this article have no relevant financial relationships to disclose per the JVS policy that requires reviewers to decline review of any manuscript for which they may have a competition of interest.

0741-5214/$36.00

Published by Elsevier Inc. on behalf of the Society for Vascular Surgery.

doi:10.1016/j.jvs.2010.10.133

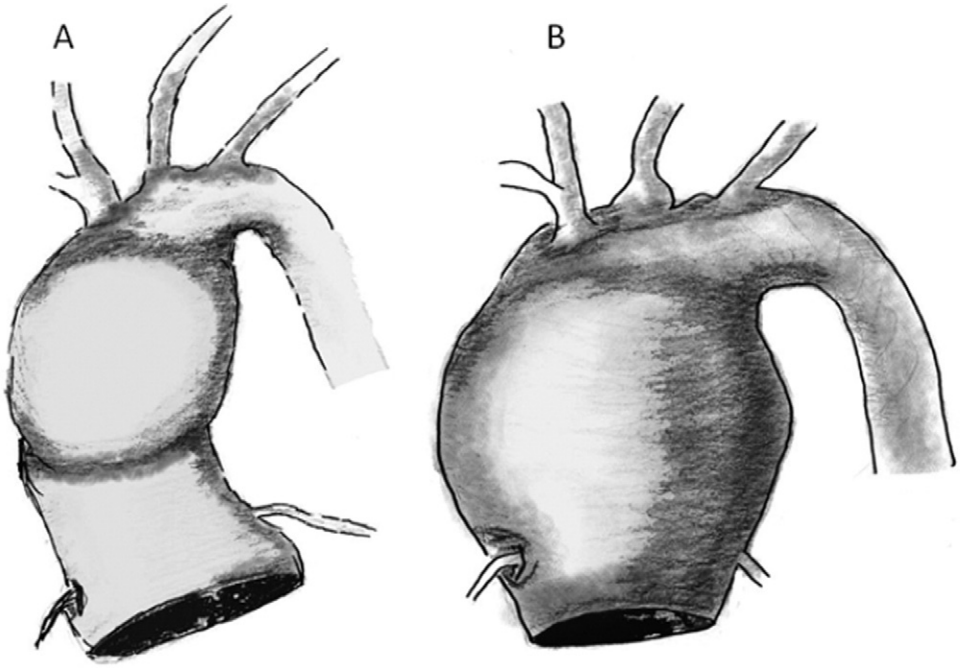

Fig 1. A, A tubular-shaped aneurysm. **B,** A conical shaped aneurysm.

chronic type A dissections can be treated with a tubular endograft when the aortic valve and the coronary arteries are not involved.[5]

An analysis in our clinic of 30 consecutive patients admitted with ascending aortic pathology showed that the ascending aneurysms in 75% had a conical shape without a proximal landing zone. Only in a few cases did the ascending aorta have a tubular configuration with a long proximal landing zone of at least 2 cm (Fig 1). This makes oversizing and an optimal graft configuration particularly important. Only patients without connective tissue disorders, clinically relevant aortic incompetence, stenosis, or concomitant coronary artery disease can be considered for an endovascular procedure. We report our results in a series of patients with aneurysms or various aortic pathologies who were scheduled for stent grafting.

METHODS

Only patients with ascending aortic pathology who were considered unfit for open surgery were treated with an endograft. Unfit or high risk was defined as an American Society of Anesthesiologists (ASA) classification ≥IV, age ≥70, a history of myocardial infarction, or renal insufficiency, severe chronic obstructive pulmonary disease (COPD), compensated or prior heart failure, stroke, uncontrolled hypertension, or a combination of these factors. A consensus conference was held before surgery with cardiologists, anesthetists, and vascular surgeons. Cardiac surgeons were included in the decision-making process when the cardiologist in charge wanted another surgical opinion.

The analysis excluded patients where the ascending aorta or zone 0 was the proximal landing zone for an aortic arch stent graft. Patients with acute type A dissections were not included because we did not have Internal Review Board approval for endovascular treatment of these emergency cases. Also excluded were patients with malperfusion or any preoperative unstable clinical condition after type A dissection, and patients with severe aortic valvular disease, including aortic valvular incompetence as a consequence of an acute type A dissection, coronary artery disease requiring surgery, and any kind of connective tissue disorder.

Included were patients with intramural hematoma localized to the ascending aorta and complaining about chest pain, floating thrombus after chronic type A dissection and multiple emboli, and penetrating aortic ulcers. Also included were aneurysm patients without aortic valve incompetence or significant dilatation of the aortic annulus requiring composite graft replacement of the aortic valve and the ascending aorta.

According to our protocol, patients with asymptomatic penetrating aortic ulcers were initially managed conservatively. Patients in whom symptoms developed that did not resolve or who continued complaining about chest pain were classified as symptomatic, and endovascular exclusion was discussed with the patient.[5] Only aneurysm patients with an aortic diameter of ≥6.0 cm were considered for an endograft.

All procedures were performed by the two senior authors (R.R.K. and R.K.). When preoperative computed tomography (CT) imaging showed severe calcification of the aortic arch or thrombus lining temporary, clamping of the carotid arteries before wire and catheter introduction was performed. An extracorporeal bypass from the right groin to both carotid arteries with a heat

exchanger, membrane oxygenator, and a roller pump was established and maintained during the procedure.[6,7] Acetylsalicylic acid (100 mg/d) was administered before the procedure and continued indefinitely. All patients received a 300-mg loading dose of clopidogrel, followed by 75 mg daily for at least 6 to 12 months. During the intervention, the patient received weight-adjusted intravenous heparin to achieve an activated clotting time of 300 to 350 seconds for the duration of the procedure.

Device success was defined as stable device placement and adequate function as assessed by CT angiography scan and echocardiography. Acute procedural success was defined as device success with absence of periprocedural major adverse cardiovascular and cerebral events ≤48 hours after device implantation. Clinical adverse events were adjudicated by an independent clinical events committee. Major adverse cardiovascular and cerebral events consisted of death from any cause, myocardial infarction (creatine kinase-myocardial band more than twice the upper limit of normal), cardiac tamponade, stroke (as assessed by routine neurologic assessment before and after procedure and before hospital discharge), emergent percutaneous coronary intervention, cardiogenic shock, endocarditis, or aortic dissection. Major bleeding was defined as hemorrhage requiring surgery or ≥3 units of blood transfusion.

The exact length of the graft required was determined intraoperatively with a measuring catheter. Because of the conical shape of the ascending aorta in aneurysm cases, preoperative centerline measurement did not yield the information necessary for precise planning. The length of the stent graft depended on the length of the outer curve of the ascending aorta, which was regularly longer than the distance determined by centerline measurement (Table).

All operations were performed with the patient under general anesthesia. In addition to our monitoring protocol for thoracic endovascular aneurysm repair, transesophageal ultrasound imaging was performed to control cardiac and valvular function.

Cardiac arrest was induced with adenosine administration when required. A temporary ventricular pacemaker was placed through the jugular vein. Accurate deployment required lowering of the blood pressure ≤70 mm Hg to avoid ballooning of the left ventricle when aortic regurgitation was provoked after passage of the introducer sheath into the left cardiac chamber. After road map angiography, selective coronary angiography was performed to outline the origin of the coronary arteries.

An ultrastiff guidewire (Lunderquist, Cook, Bjaeverskov, Denmark) was placed into the left ventricle after passage of the aortic valve with a vertebral catheter over a 0.035-inch Terumo guidewire (Terumo Medical Corp, Somerset, NJ). The endograft was carefully placed across the aortic valve (Fig 2) until the nose cone of the endograft was completely inside the left ventricle. This provoked aortic regurgitation controlled by ultrasound imaging, and the graft was deployed just distally to the coronary sinus, trying to avoid kinking of the graft.

Table. Patient's characteristics and intraoperative data

	Patients (N = 11)	
Variable[a]	*Group I*[b]	*Group II*[c]
Patients	7 (63.6)	4 (36.3)
Age, years	74 (69-82)	71 (67-84)
Gender		
Male	3 (27.2)	2 (18.1)
Female	4 (36.3)	2 (18.1)
Chronic renal disease	2 (18.1)	0 (0)
Cardiac disease[d]	5 (45.4)	4 (36.3)
Previous cardiac valve surgery[e]	2 (18.1)	1 (9.0)
CVD (previous TIA/CVA)	2 (18.1)	0 (0)
Hypertension	6 (54.5)	4 (36.3)
Diabetes	3 (27.2)	2 (18.1)
Smoking		
Former smoker	2 (18.1)	1 (9)
Current smoker	5 (45.4)	3 (27.2)
Never smoked	0	0
Hypercholesterolemia	4 (36.3)	2 (18.1)
Previous aortic surgery	1 (9)	1 (9)
ASA score	4.6 (4-5)	4.7 (4-5)
Aortic diameter, mm	68.1 (60-79)	
Length of aorta covered cm	10.09 (7-14)	8.75 (8-10)
Type I leak	1 (9)	0 (0)
Follow-up, months	9.1 (2-19)	12.5 (6-20)
Stroke	1 (9)	0
Death	1 (9)	0

ASA, American Society of Anesthesiologists; *CVA,* cerebrovascular accident; *CVD,* cardiovascular disease; *TIA,* transient ischemic attack.
[a]Categoric data are expressed as number (%); and continuous data are presented as mean (range).
[b]All aneurysm patients.
[c]Patients with chronic uncomplicated type A dissection, intramural hematoma, floating thrombus, or penetrating aortic ulcer.
[d]Includes previous myocardial infarction, coronary artery bypass grafting, or percutaneous angioplasty.
[e]Two patients had prosthetic aortic valve repair, and 1 patient had a conduit.

After full deployment, leaving the guidewire still in the ventricle, the sheath was removed. Contrast was injected to check the exact position of the endograft in relation to the coronary sinus. The ultrastiff wire was exchanged for a standard 0.035-inch guidewire, and a pigtail catheter was positioned close to the coronary sinus. An injection of 30 mL of contrast was given to rule out obstruction of the coronary arteries. The kind of graft used depended on the size required. When a graft >42 mm was necessary, we used the Valiant device (Medtronic, Minneapolis, Minn); in other cases, the Cook ProForm graft was used.

Tracking of the stiff wire during the entire procedure was essential to avoid ventricular perforation. At the end of the procedure, ventriculography was performed to rule out any damage to the left ventricle or the valve apparatus. In case of any electrocardiogram (ECG) changes, coronary angiography was added before the catheter and sheaths were removed (Fig 2, *C*). Before discharge, contrast-enhanced CT angiography and a cardiac ultrasound examination were performed.

All cases were approved by the Internal Review Board after presentation to a steering committee guided by cardiac specialists. Patients were informed about the experi-

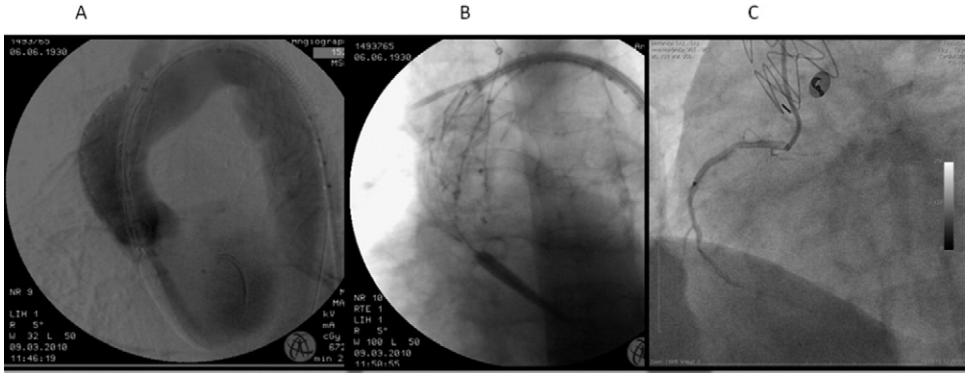

Fig 2. A, Aortic regurgitation is shown after passage of the endograft through the aortic valve. The tip of the endograft is in the left ventricle. **B,** The endograft has been partially deployed. **C,** Control coronary angiography after stent deployment shows the bare springs are near the right coronary artery.

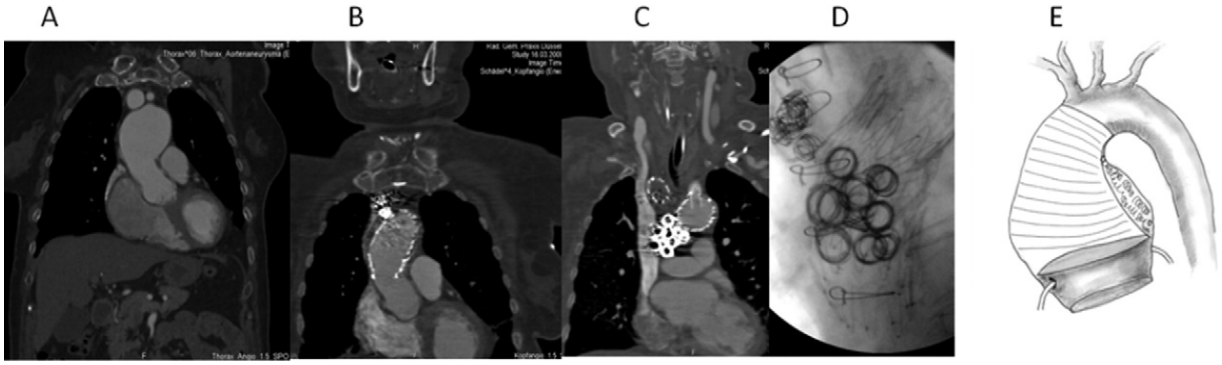

Fig 3. A, The proximal landing zone in a conical-shaped ascending aortic aneurysm is shown after aortic valve repair with a valve-bearing conduit. **B,** A type I leak was still noted after stent graft deployment. **C,** The aneurysm sac was coiled through the innominate artery. **D,** Plain X-ray film shows large-caliber coils near the endograft. **E,** Illustration shows the stent graft and coils in the aneurysm sac.

mental character of the treatment, and other options, surgical as well as conservative, were explained to them.

RESULTS

Between 2008 and June 2010, 11 patients were scheduled for stent graft exclusion of ascending aortic pathology. The Table summarizes the indications for treatment in the endovascular group. An iliac conduit to accommodate the 24F introducer sheath was required in one patient. In two patients the right carotid artery was chosen as an access vessel after cervical cut down without any neurologic sequelae. In five patients, because of discrepancies in length measurements and sizing, the thoracic endograft was cut to length intraoperatively after partial deployment on the operating table and reloaded to avoid covering of the innominate artery. The mean length of the ascending aorta covered was longer in aneurysm patients compared with patients with various types of pathology (Table).

In all cases, the tip of the endograft was bent to get a curved configuration after immersing the nose cone in cold water. Because the graft was introduced into the left ventricle, it had to adapt to the configuration of the left ventricle to avoid perforation.

One type Ia leak was found in an 81-year-old patient. When the stiff guidewire was placed in the left ventricle, she experienced immediate aortic incompetence and ventricular tachycardia. The stent graft was placed too distally from the sinotubular junction. The condition of the patient did not permit placement of a second short graft to seal the leak. She was discharged after an uneventful recovery. After a follow-up of 12 months, she still had a type I leak but refused any further treatment.

In patient 2, a type Ib leak was seen after stent graft deployment. We decided to debranch the innominate artery with a cervical crossover bypass to enlarge the distal landing zone and to deploy a distal extension. In addition, using the innominate artery as an access, coils were placed directly into the sac of the ascending aortic aneurysm, and the origin of the innominate artery was occluded with an Amplatz (AGA Medical Corporation, Plymouth, Minn) occluder (Fig 3, *A* and *B*). A postoperative CT scan showed complete exclusion of the ascending aneurysm from blood flow.

In one patient, the bare springs of the graft that was deployed proximal to the sinotubular junction prevented satisfactory closing of the aortic valve. The patient experi-

Fig 4. A, A floating thrombus in ascending aorta. **B,** Coronal section of contrast-enhanced computed tomography scan shows the exact placement of stent graft. **C,** A 3-dimensional reconstruction shows the stent graft location is close to the aortic valve and coronary sinus.

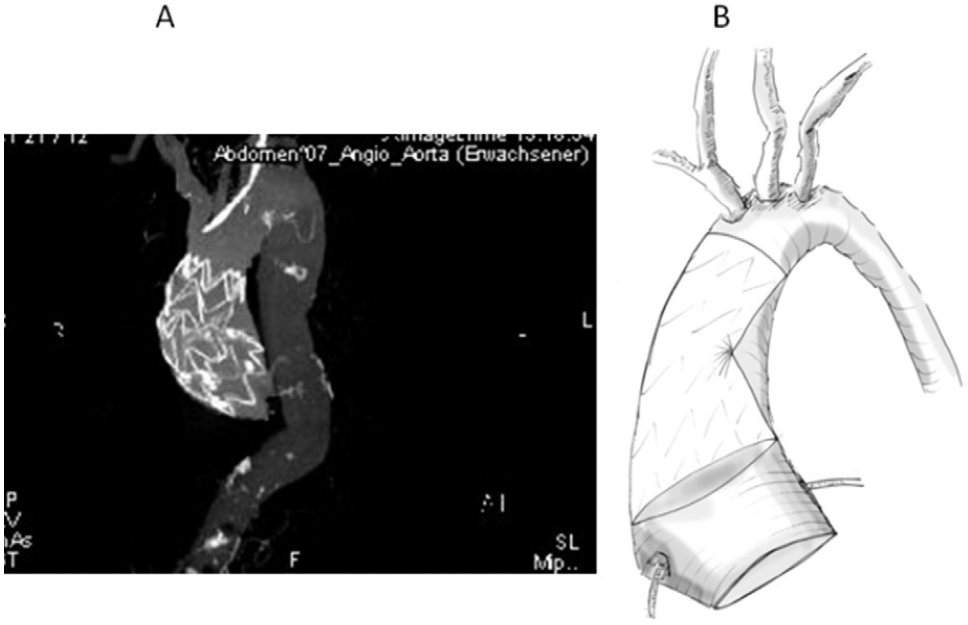

Fig 5. A, A computed tomography reconstruction shows the stent graft. **B,** Illustration shows kinking of the stent graft.

enced severe aortic incompetence combined with mitral valve regurgitation due to the retrograde jet. A 42-mm compliant balloon was used to pull back the stent graft. The patient was discharged home with regular myocardial function and an aortic regurgitation fraction of 8%.

In two cases, a kink and compression of the stent graft at the lesser ascending aortic curvature was seen due to the disparity between the lengths of the outer curvature compared with the inner curvature. This did not have any hemodynamic consequences and did not have an effect on aneurysm exclusion (Figs 4 and 5).

In two patients, the distal bare stents of the stent graft were deployed at the level of the origin of the innominate artery, and the bare springs protruded into the innominate artery. A postoperative ECG-triggered and contrast-enhanced control CT scans showed a completely stable position of the stent graft with no residual movement during cardiac cycle.

Combined mortality and morbidity was 18% (two patients). Ten patients were discharged to home or to a lesser dependency unit. Two major complications occurred: One patient who had recovered from two previous myocardial infarctions, died immediately after successful deployment of the stent graft. The stiff guidewire had perforated the wall of the left ventricle. Emergency sternotomy was performed and the rupture site was closed, but the patient died

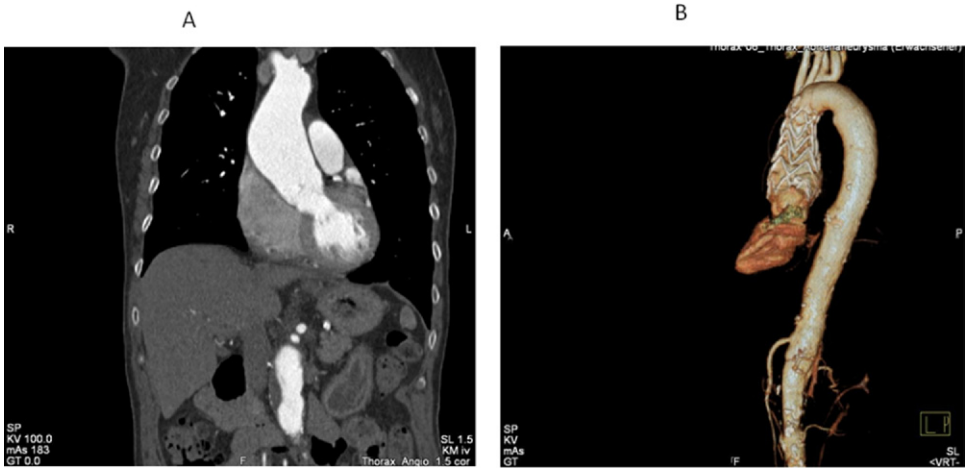

Fig 6. A, A conical-shaped aneurysm. **B,** A 3-dimensional reconstruction after aneurysm exclusion.

of multisystem organ failure 24 hours later. A second patient sustained a massive stroke but was discharged to a rehabilitation center. This event caused a change of our protocol, as mentioned above. Two patients required prolonged ventilator support: Both had severe COPD and were heavy smokers. They were discharged to home after prolonged intensive care unit treatment.

DISCUSSION

Ascending aortic dilatation may be caused by intrinsic pathology of the aortic wall or hemodynamic factors caused by a stenotic aortic valve. High velocity and turbulent flow downstream of the stenosis place mechanical stress on the aortic wall (Fig 6).

The thin wall of the ascending aorta does not permit aggressive over dilatation. The graft was deployed in most cases without any additional balloon dilatation. The walls of the aortic sinus of Valsalva are considerably thinner than the wall of the aorta. Hooks or bare springs should therefore be deployed a safe distance from the sinus and the origin of the coronary arteries to avoid erosion and perforation.

One of our first patients sustained a postoperative stroke. Calcifications and thrombus lining of the ascending aorta and aortic arch were the main parameters for increased stroke risk. To avoid any further complications, temporary clamping of the carotid arteries and extracorporeal bypass were performed. We considered an alternative placement of filter wires but expected temporary clamping and shunting to be safer although more invasive.[7] This will probably change in the near future. For catheter-based aortic valve repair, transfemorally placed meshes covering temporarily the inner surface of the aortic arch are under clinical evaluation.

Access can be a problem, because a 24F access sheath was required in most aneurysm cases. In two patients with severe calcification of the iliac vessels, we had to use the left carotid artery as an access, which proved to be uneventful. Alternatively, a small thoracotomy can be used to deploy the endograft through the apex of the heart.

So far, no dedicated grafts have been developed for the ascending aorta. Because most aneurysms have conical shape, a stent graft designed for type A dissection is not necessarily suitable for aneurysm repair. The anchoring zone of a few millimeters only requires fixation with hooks, significant oversizing, and coil deployment into the sac of the aneurysm if necessary. From our experience, a graft without bare springs is preferred to avoid compromising aortic valve closure. The tip or nose cone of most commercially available grafts should be shorter than the tips of the grafts designed for deployment in the descending aorta.

The aortic impulse, which is directly proportional to the mean blood pressure, the cross-sectional area of the aorta, and the duration during systole, varies inversely with the distance from the aortic valve. In stent grafting of the aortic arch and the descending aorta, high aortic impulses can cause significant pulsate motion of the arch and inadvertent movement of the stent graft. In the future, more active fixation with a stapler would probably permit safer deployment, fewer type I leaks, and better long-term performance. Especially when treating more advanced stages of aortic pathology, a valve-bearing conduit with fenestrations for the coronary arteries will be necessary.

In most cases, a mismatch exists between the length of the inner curvature of the ascending aorta and the outer curvature, which can easily result in a kink of the graft. Instead of using one graft, two or three stacked grafts only 5 cm in length could solve this problem.

To permit exact graft deployment and to prevent accidental covering of the coronary arteries, temporary cardiac arrest as well as rapid ventricular over pacing was used. Lee et al[8-10] have advocated partial right atrial inflow occlusion for thoracic endovascular aneurysm repair to induce controlled hypotension. In our patients, due to passage of the endograft through the aortic valve, we caused abrupt regur-

gitation across the aortic valve. Yet, the retrograde approach can also cause temporary mitral valve insufficiency. Intraoperative echocardiography shows a direct relationship between blood pressure, duration of aortic insufficiency, and volume overload of the left ventricle. Partial right atrial inflow occlusion could therefore be the safest way to permit accurate graft deployment.

PROBLEMS AND TECHNICAL PITFALLS

This is only a small study with an inhomogeneous group of patients. Several issues must be addressed before a routine use can be advocated outside of studies. There should be dedicated grafts for ascending aneurysms and for acute dissections without bare springs. The problem of cerebral emboli must be solved.[11] Temporary cross clamping and cerebral perfusion with an extracorporeal pump is relatively safe but further increases the invasiveness of the procedure. We did not have any evidence of emboli in the carotid arteries. Precise deployment of the graft adjacent to the coronary arteries is essential in aneurysm patients. In most cases, there is a landing zone of a few millimeters only, deployment too distal from the sinotubular junction results in kinking of the graft and a subsequent type I leak.

We do not have long-term follow-up data in these few cases. A mean follow-up of 9 months only, although without any changes in graft performance, is too short to permit any conclusions about the long-term durability of this technique. The hemodynamic consequences are unknown. Theoretically, the elasticity of the ascending aorta should decrease after graft deployment. It is unknown whether this affects blood pressure regulation, coronary artery perfusion, or the stability of the endograft. Reduced aortic wall elasticity can be associated with increased aortic regurgitation and left ventricular hypertrophy.[12] Ascending aortic aneurysms already have reduced aortic wall elasticity associated with various degrees of aortic regurgitation and ventricular hypertrophy. We can only assume that deployment of a stent graft will not cause further deterioration of cardiac function. One of the objectives of future studies must be the measurement of the circumferential aortic strain and deformation using cardiac gated image data.

CONCLUSIONS

Stent grafting of the ascending aorta is technically feasible but should be reserved for selected high-risk patients only, preferably in centers where vascular specialists cooperate closely with interventional cardiologists. Cardiac surgery with cardiopulmonary bypass and, if necessary, deep hypothermia is still the gold standard when treating ascending aortic aneurysm, although still associated with significant morbidity and mortality.[13] Stent graft exclusion of more advanced and complex ascending aortic aneurysms should be reserved for high-risk patients only in centers with the necessary skills to perform transvalvular cardiac procedures. This may change in the future when more dedicated grafts become available.

REFERENCES

1. Uchida K, Imoto K, Yanagi H, Machida D, Okiyama M, Yasuda S, et al. Endovascular repair of ascending aortic rupture: effectiveness of a fenestrated stent-graft. J Endovasc Ther 2010;17:395-8.
2. Gao WZ, Massimo CG, Ming L. Deployment of endograft in the ascending aorta to reverse type A aortic dissection. Asian J Surg 2003; 26:117-9.
3. Lin PH, Kougias P, Huynh TT. Endovascular repair of ascending aortic pseudoaneurysm: technical considerations of a common carotid artery approach using the Zenith aortic cuff endograft. J Endovasc Ther 2007;14:784-98.
4. Heye S, Daenens K, Maleux G, Nevelsteen A. Stent-graft repair of a mycotic ascending aortic pseudoaneurysm. J Vasc Interv Radiol 2006; 17:1821-5.
5. Eggebrecht H, Plicht B, Kahlert R, Erbel R. Intramural hematoma and penetrating aortic ulcer: indications to endovascular treatment. Eur J Vasc Endovasc Surg 2009;38:659-65.
6. Wales L, Howard A, Bohm N, Munneke G, Loftus I, Thompson M. The use of an extra-corporeal graft to maintain cerebral perfusion during thoracic endovascular aneurysm repair. Eur J Vasc Endovasc Surg 2007;34:176-8.
7. Schönholz C, Ikonomidis JS, Hannegan C, Mendaro E. Bailout percutaneous external shunt to restore carotid flow in a patient with acute type A dissection and carotid occlusion. J Endovasc Ther 2008;15: 639-42.
8. Lee WA. Partial right atrial inflow occlusion for TEVAR. Endovasc Today 2009;10:39-44.
9. Lee WA, Martin T, Gravenstein N. Partial right atrial inflow occlusion for controlled systemic hypotension during thoracic endovascular aortic repair. J Vasc Surg 2008;48:494-8.
10. Lee WA, Martin TD, Hess PJ, Beaver TM, Huber TS. Maldeployment of the TAG thoracic endograft. J Vasc Surg 2007;46:1032-5.
11. Buth J, Harris PL, Hobo R, van Eps R, Cuypers P, Duijm L, et al. Neurologic complications associated with endovascular repair of thoracic aortic pathology: incidence and risk factors. A study from the European Collaborators on stent/Graft Techniques for Aortic Aneurysm Repair (Eurostar) registry. J Vasc Surg 2007;46:1103-10.
12. Morrison TM, Choi G, Zarins CK, Taylor CA. Circumferential and longitudinal cyclic strain of the human thoracic aorta: age-related changes. J Vasc Surg 2009;49:1029-36.
13. Okita Y, Ando M, Minatoya K. Early and long-term results of surgery for aneurysms of the thoracic aorta in septuagenarians and octogenarians. Eur J Cardiothorac Surg 1999;16:317.

Submitted Sep 24, 2010; accepted Oct 24, 2010.

INVITED COMMENTARY

Tara Marie Mastracci, MD, *Cleveland, Ohio*

Surgery, many say, is like riding a bike. Regardless of the challenge of the terrain, the sophistication of the vehicle, or the time passed since the cyclists' last journey, basic principles prevail. The advent of endovascular technology has given the field of vascular surgery a lesson in self-directed learning and has taught us the importance of respecting the long-held truths of aortic surgery. We are, in many cases, experienced cyclists with constantly evolving bicycles.

With calculated steps over 20 years, a primitive endovascular graft for an infrarenal aneurysm[1] has evolved into branched and fenestrated technology to treat thoracoabdominal disease, while staying true to surgical principles. The natural progression of this